A practical approach to Stereotactic Radiation Therapy plan verification with matrix detectors

Kassymkhan TURIKBAYEV

turikbayevk@gmail.com

Supervisors:
Dr. Anna DELANA
Dr. Francesco ZIGLIO

St.Chiara Hospital, Trento, Italy

Azienda Provinciale per i Servizi Sanitari
Provincia Autonoma di Trento

Prospective/Objective: The aim of this work was to evaluate the impact of dose rate and fields dimension on the Octavius 1500 (OD1500) and Octavius 1600SRS (OD1600) detectors' measurements and to define a calibration procedure for the two matrices, in order to verify SBRT and SRS VMAT plans (6MV FFF and 10MV FFF energies).

Materials and methods: This first part of the work evaluated the response of OD1500 and OD1600 detectors (ODs) to different fields and dose rates for 6 MV, 10 MV and 6 MV FFF, 10 MV FFF energies of an the Elekta™ Versa HD accelerator. Output factors (OF) were compared to the measurements performed during the linac's acceptance test and annual QA verifications, with the dosimeters of reference: ionization chambers (PTW Semiflex 3D, PTW PinPoint, PTW micrioLion) and solide state detector (PTW Microdiamond). The second part of the work was focus on the determination of matrices' calibration factors corrections for SBRT QA plan verifications. The matrices were cross-calibrated ionization chambers PTW Pinpoint and PTW Semiflex 3D, with a 5x5cm2 field at 6MVFFF and 10MVFFF energies. Dose measurements were acquired for small fields varying dose rates to determine the matrix's calibration's correction factors (k_{fs}^{dr}), as a function of field dimension and dose rate. k_{fs}^{dr} values were also compared with the literature. The proper k_{fs}^{dr} was defined for 6 SBRT/SRS plans that were previously analyzed and characterized by their mean segments' dimension and dose rate. The gamma analysis were then performed to compare calculated dose maps and measured dose maps, for each plan (with dose and distance tolerances of 2%, 2mm), before and after the corrections.

Results: OF measured with the OD1500 detector are in good agreement with the reference dosimeters: at field 4×4cm2 and 3×3cm2, deviations were within -0.5% and -1.5%, at field 2×2cm2 the discrepancy is higher, -3.8%. OF measured with the OD1600 in good agreement with the reference dosimeters: at field 4×4cm2 and 3×3cm2, deviations are within 0.3% and 0.8%, at field 2×2cm2 the discrepancy is 2%. Estimated matrix correction factors for the OD1500 are: 1.013±0.003 (for field 3×3cm2) and 1.082±0.003 (for field 2×2cm2) for energy 10MV FFF; 1.014 (field 3×3cm2) and 1.038 (field 2×2cm2) for energy 6MV FFF. These results are in good agreement with the literature; the correction factors for the field 2×2cm2. Matrix correction factors for OD1600 are 1.0 (5×5cm2), 0.97 (3×3cm2) and 0.95 – 0.93 (2×2cm2) for energy 10MV FFF depends on dose rate, 1.0 (5×5cm2), 0.99 (3×3cm2) and 0.98 (2×2cm2) for energy 6MV FFF at maximum dose rate.

Conclusion: Two matrix detectors with OCTAVIUS 2D were analyzed to perform routine QA measurements for treatments SRS/SBRT plans. Our practical approach to correct the matrices' dependence on field size and dose rate give good results in terms of gamma analysis for the SBRT/SRS plans evaluated, but further verifications should be performed to confirm our correction factors estimations.

Dosimetric optimization and evaluation of hepatocellular carcinoma treatment effect prediction in Y-90 transarterial radioembolization

Laura Grikke

lauragrikke@gmail.com

Supervisors:
Dr. Gian Luca Poli
Dr. Claudia Bianchi

Prospective/Objective: This study aimed to optimize and standardize the pre- and post- dosimetry protocols for ^{90}Y TARE at ASST Papa Giovanni XXIII Hospital (Bergamo, Italy) and assess the predictive value of voxel dosimetry for treatment outcomes, including radiological response, adverse events and patient overall survival in HCC patients.

Materials and methods: In this retrospective study 133 HCC patients treated with ^{90}Y microspheres from 2013 to 2021 were analysed. Of those 95 were treated with resin microspheres, 38 with glass microspheres. The pre- and post-dosimetry protocols were optimized based on EANM guidelines, utilizing the Planet Dose software. Pre-dosimetry was done for all the patients and the calculated doses were used for statistical analysis. Post-dosimetry was performed for patients treated after installation of the PET/CT system in 2019. Association between mean dose delivered to the lesion and complete radiological response (CR) was assessed by Wilcoxon-Mann-Whitney test, when the dose was considered as a continuous variable, and by chi-square test when the dose was dichotomized using the best cutoff identified by ROC curve. Univariate and multivariable Logistic Regression models were fitted to identify predictors of CR. Cox Proportional-Hazard Regression models were fitted to identify predictors of death. A comparison of doses calculated during pre- and post-dosimetry was performed before and after the optimisation of PET/CT acquisition protocol.

Results: The optimal reconstruction for pre-treatment dosimetry with ^{99m}Tc-MAA with Siemens 'Symbia' SPECT/CT was determined as Flash 3D, 8 subsets, 8 iterations, and no filtering. For resin microspheres from the ROC curve plotted for mean dose delivered to the lesion predicting CR, a cutoff dose was found to be 233.2 Gy (AUC = 0.6191). A significantly higher proportion of CR was found in the patients who received a dose ≥ 233.2 Gy (49.1% of CR with higher doses vs. 23.8% of CR with lower doses, p=0.012), as well as a reduction of risk of death by 42% (HR=0.58, 95% CI 0.34-1.01, p=0.054). The number of patients with complete radiological response treated with glass microspheres was too low to implement a statistical model. No lung toxicity was observed for any of the patients involved in this study. No correlation between the dose delivered to the normal liver and adverse events was found during the statistical analysis. Comparison of pre- and post-dosimetry was performed for 34 patients before the optimisation of PET/CT protocol. In 8 patients mean lesion dose discrepancies of >40% were found. After the optimisation all the lesion doses were within 40% when the pre- and post-dosimetry was compared.

Conclusion: Dose to the lesion is a significant predictor of CR for resin microspheres, the mean dose delivered to the lesion should be at least 233.2 Gy. In patients receiving at least this dose, a reduction of risk of death was observed. The absence of lung toxicity and the lack of correlation between normal liver absorbed dose and adverse events suggests potential under-treatment, advocating for increased delivered doses in future interventions.

ASST Papa Giovanni XXIII Hospital (Bergamo, Italy)

Sistema Socio Sanitario
Regione Lombardia
ASST Papa Giovanni XXIII

Comprehensive Assessment of Breast Cancer Treatment: Monaco TPS IMRT/VMAT Templates and Positioning using XVI/ $Catalyst^{TM}$

Phantsi Tsolo D.

tphantsi@ictp.it

Supervisors:
Dr. Spiazzi Luigi

ASST Spedali Civili di Brescia,Brescia Italy

Prospective/Objective: The first part of the thesis focuses into the development and optimization of IMRT and VMAT templates on Monaco TPS for breast cancer treatment. The second objective involves a comprehensive analysis of positioning shifts in breast cancer treatments, specifically comparing patients treated using XVI+$Catalyst^{TM}$ positioning to those treated using XVI positioning alone. Additionally, a subgroup analysis compares XVI versus $Catalyst^{TM}$ shifts. The study aims to evaluate the efficacy and equivalence of these positioning approaches.

Materials and methods: The methodology begins with the transfer of patient data, including RT Plan, Prescription, RT Structure, RT Dose and DICOM Images from Pinnacle TPS to Monaco TPS for template creation. The testing methodology for template assessment involves a direct comparision of Monaco created templates with established reference treatment plans, allowing for an in depth assessment of dosimetric parameters and plan quality. Additionally, prior to the template and reference plan comparison, an in-depth analysis of the coherence and reliability of Dose-Volume Histogram (DVH) data generated by both Monaco and Pinnacle TPS was conducted. Independent Samples T-Tests were emplyed for DVH data analysis. The second part of the thesis is a comprehensive analysis of positioning shifts in breast cancer treatments from August to Novemebr 2023. It compares a group of patients of XVI+ $Catalyst^{TM}$ positioning and a group of XVI positioning alone. The study involved 45 patients, and the total valid sample size (N) across all patients was 260 (N: 115 XVI+CAT and N: 145 XVI Alone). The study used Independent samples T-Test to find the statistical differences in lateral (LAT), longitudinal (LON) and vertical (VER) positioning components. Futher analysis were on XVI vs $Catalyst^{TM}$ shifts on a group of 15 patients, with a (N) sample size of 96 data points. Paired sample T- Test was used on this case.

Results:. Using Independent samples T-Test for 48Gy, 40.05Gy and 26Gy protocols, the study found p-values of p=0.992602, p=0.939864 and p=0.984541 indicating the equivalence of Monaco and Pinnacle TPS in DVH calculations. Moreover, following comparisions of Monaco- created templates with Pinnacle reference plans, using Independent Samples T-Tests for 48Gy (p=0.995776), 40.05Gy (p=0.99082564) and 26Gy (p=0.991866) demostrated large p values, suggesting the equivalence of Monaco templates and Pinnacle in meeting the specified constraints for breast cancer protocols. In the positioning analysis of XVI+$Catalyst^{TM}$ vs XVI alone, no statistically significant differences are observed in LAT(p=0.926) and LON(p=0.631) components. However, the vertical (VER) positioning results reveal a significant difference (p-value:0.030). For analysis of XVI vs $Catalyst^{TM}$ shifts, a significant difference is in longitudinal shifts (p-value: 0.007). Lateral (p-value: 0.450) and vertical shifts (p-value: 0.134) demostrate comparability.

Conclusion: Statistical analysis across breast cancer protocols indicates high p-values, confirming equivqlence between Monaco and Pinnacle plans. Monaco templates are deemed safe for treatment planning. XVI+$Catalyst^{TM}$ vs XVI alone reveals comparable lateral and longitudinal positioning but a significant difference in vertical positioning. XVI vs $Catalyst^{TM}$ suggest attention in replacing XVI with $Catalyst^{TM}$ especially in scenarios requiring precise longitudinal positioning.

Minimax robust optimization of VMAT in stage III lung cancer patients: a dosimetric comparison with the PTV-based approach

Almijbari Raja Faraj

ralmijba@ictp.it

Supervisors:
Dr. Gianfranco Loi

AOU Maggiore della Carità Novara, Italy

Prospective/Objective: to study the performances of the Minimax Robust Optimization (MRO) approach for Volumetric Modulated Arc Therapy (VMAT) planning compared to the standard (PTV-Based) strategy to treat stage III lung cancer patients. The research aims to quantify the advantages of MRO in lung cancer settings by robust evaluation of standard plan quality metrics like DVH points dose conformity and homogeneity indexes.

Materials and methods: Standard and robust VMAT plans were generated by the TPS Raystation v12b, selecting a cohort of ten patients from a Stage III-NSCLC publicly available archive. For both plans, a 6MV photon beam from a clinically commissioned Linac Varian Trilogy equipped with a Millennium MLC system was employed. Treatments were planned using a synthetic CT obtained from an average of 10 phases of a 4D-CT scan; the same 4D sequence was used to generate the ITV for the standard plan arm. Systematic and random positioning errors from baseline and motion-induced shifts were evaluated on 14 patients, coming from the same archive, with 5 consecutive verification 4D-CBCT scans. A single population-based margin yielding ±5mm, ±8mm, and ±5mm in the LL, SI, and AP directions was derived and used for PTV generation in the standard arm and to set the robust optimization parameters in the robust one. The dose distributions were analysed using the TPS robust evaluation tool, comparing the values obtained for all the selected dose metrics in all the simulated geometrical uncertainty scenarios. Isotropic shifts of ±3, ±5, and ±8mm magnitude were applied to evaluate the robustness of the two approaches against the geometrical uncertainties. Descriptive statistics and a non-parametric Wilcoxon sign test were carried out to assess if the differences were statistically significant.

Results: No significant differences were found in terms of CTV coverage for uncertainties up to 5 mm. A statistically significant difference was found ($p= 0.001$) in the worst-case scenarios, slightly exceeding the robustness parameters. In this case, the robust plans underperformed the standard ones, highlighting their sensitivity to errors exceeding the limits set in robust optimization. In terms of dose conformality, robust plans significantly outperformed the standard ones without affecting dose homogeneity. The dose of OARs was systematically lower in the robust arm, with clinically and statistically significant differences ($p< 0.0001$). To cite the closest OAR to CTVs, the reduction of mean and maximum dose to the oesophagus was respectively 1.41±1.55 Gy and 5.79±7.86 Gy. Finally, robust plans required less modulation as a result of a significant reduction in the Monitor Unit number ($p = 0.012$).

Conclusion: MRO led to improved target coverage and dose reduction to OARs with a lower complexity profile without compromising the treatment safety with potential clinical benefits in advanced lung cancer treatments.

Performance assessment of different reconstruction algorithms, performed with AAPM Task Group 233 CT task-based image quality metrics.

RANDRIAMANANTENA Steph Eric
randriamanantenasteph@gmail.com

Supervisors:
Dr. Paola Bregant
Dr. Michele Signoriello

Ospedalle Maggiore Trieste, Italy

Prospective/Objective: In the past few years, Computed Tomography (CT) vendors introduced Artificial Intelligence Deep Learning Reconstruction (AI DLR) algorithm to overcome the limitation of Iterative Reconstruction (IR) algorithm. The purpose of this work is to provide a qualitative characterization of IR and AI DLR algorithms of different commercial vendors, focusing on image quality protocol optimization based on the qualitative metrics suggested by AAPM TG 233 protocol.

Materials and methods: A 128 slices GE Revolution System and 320 slices Canon Aquilion One Prism were used in this study to assess image quality of advanced reconstruction algorithms. Acquisition were carried out using Catphan phantom model 600. A clinical head protocol was selected on GE Revolution CT. Different acquisitions were performed with three slice thickness (1.25, 2.5 and 5 mm) and CTDIvol values equal to 18.82, 18.88 and 20.77 mGy respectively. Images were reconstructed using one level of iterative ASIR (ASIR50) and AI DLIR with three different strengths (LOW, MEDIUM and HIGH).

On Canon Aquilion One Prism, both head and body protocols were used. Data were acquired with CTDIvol values equal to 52.7 mGy for head and respectively 3.2 and 6.3 mGy for body, with three slice thickness (1, 3, 5 mm). Images were reconstructed using AIDR 3D as Adaptive Iterative Dose Reduction algorithm and Advanced intelligent Clear-IQ Engine (AiCE) based on deep learning reconstruction technique. Task-based Transfer Function (TTF) and Noise Power Spectrum (NPS) were computed. Detectability Index (d') was calculated using the nonprewhitening matched with eye filter (NPWE) model observer.

Results: Generally, for each slice thickness the ASIR-50 shows a slightly superior or comparable values of TTF50% and TTF10% for all the Catphan inserts evaluated, respect to AI DLIR and its different strengths. Starting from ASIR50 to DLIR of different levels, a substantial reduction in noise magnitude is confirmed for all the slice thickness. Considering the peak frequency, an evident shift towards lower frequencies have been found only for slice thickness of 1.25 mm and 2.5 mm. Higher detectability index was obtained for AI DLIR and the increment is more evident for high contrast inserts; it also increases varying the strength of the reconstruction algorithm. In Canon CT, using head protocol, AiCE_brain shows a shape reduction of NPS compare to AIDR 3D and AICE_Innear Ear. TTF was higher for AiCE_Inner Ear followed by AIDR 3D and AiCE_brain while an opposite result was found for detectability index. For body protocol, TTF50% and TTF10% were greater with AiCE than AIDR 3D at high contrast insert with low and high radiation dose, while a comparable values were found for low contrast inserts except for acrylic and polystyrene. The NPS was lower for DLR than IR. Higher values of DI were obtained with AiCE than with AIDR 3D at low and high radiation dose and it followed the increment of the contrast insert levels.

Conclusion. The results in this study confirm that both AI deep learning reconstruction algorithms reduce the noise magnitude and improve noise texture and detectability index. Both DLIR and AiCE have a greater impact than IR on the metric results obtained.

Brachytherapy Gynecological Cancer: Equivalent Dose Calculation in Treatment Planning System

Chabanas D. Randrianantenaina

rdeloy@ictp.it

Supervisors:
Dr. Angnes Chendi
Dr. Gabriele Guidi

Azienda Ospedaliero-Universitaria di Modena

Prospective/Objective: The aims of the thesis is evaluate the feasibility of the treatment planning system in calculating EQD2 total doses to organs at risk (OAR) and target in combined external radiotherapy and brachytherapy treatments of cervical gynecologic cancers.

Materials and methods: Thirty cervical cancer patients treated with external beam Radiation Therapy (EBRT) combined with Brachytherapy (BRT) were reviewed. The simulation CT images of EBRT and four images (CT or MRI) BRT were imported into TPS Raystation (RaySearch Laboratories, Stockholm, Sweden) to perform dose summation based on deformed images (DIR). The total doses to organ at Risk (OARs: bladder, rectum, sigmoid, bowel) and targets (HR-CTV) obtained by adding the equivalent doses in 2 Gy fraction (EQD2) from the EBRT and BRT plans were used for quantitative comparison between the three methods (TPS, Preadsheet of excel and TPS Prospective).

Results: A statistical analysis was carried out to compare the values obtained for the doses of interest using the TPS Raystation module, the values obtained for the doses of interest using the method commonly used in clinical practice (Spreadsheet of Excel) and Prospective. In combined EBRT and BRT, the mean EQD2 sum dose of bladder D2cc calculated by TPS, Spreadsheet and TPS Prospective (TPSprosp) method was (91.7 ± 14.3) Gy, (91.9 ± 9.8) Gy and (93.5 ± 16.0) Gy, respectively. The mean EQD2 sum dose of rectal D2cc calculated by TPS, Spreadsheet and TPSprosp method was (76.1 ± 15.3) Gy, (76.0 ± 11.7) Gy and (80.7 ± 17.3) Gy, respectively. For the target HR-CTV D90 calculated by TPS, Spreadsheet, and TPSprosp method was (88.1 ± 8.9) Gy, (89.13 ± 4.9) Gy and (88.8 ± 6.0) Gy, respectively. End then for HR-CTV D98 for the three method was (76.4 ± 7.9) Gy TPS, (77.5 ± 5.4) Gy Spreadsheet and (74.2 ± 15.1) Gy for TPSprosp method. In this study, all of the p-value was above to 0.05 is it no significant difference between the three method.

Conclusion: The results show that all the values for each method are in line with the dose recommended by the EMBRACE protocol. Comparisons of EQD2 dose values between TPS Raystation to spreadsheet, and TPS Raystation to Prospective do not differ greatly, and are almost similar. The values obtained by these three methods did not show any significant statistical differences. Which allows us to conclude that the module introduced by TPS Raystation could be useful in clinical practice.

Francis G. Benard

fbenard@ictp.it

Supervisor:
Dr. Sabina Strocchi

ASST Sette Laghi, Ospedale di Circolo e Fondazione Macchi, Polo Universitario

Comparing accuracy of SPICE-CT and CTQA_cp with IQWorks software in Catphan600 image analysis for X-ray computed tomography quality assessment

Prospective/Objective: The significance of software tools in evaluating CT image qaulity, during quality control assessments of CT scanners, is indisputable. Despite the longstanding use of IQWorks at Circolo Hospital Department of Medical Physics, recent compatibility issues have surfaced. This study aimed at investigating altanative freely available software; SPICE-CT and CTQA_cp, and evaluate their accuracy in comparison with IQWorks for the analysis of Catphan600 phantom images. The goal was to offer insights into the usefulness of these alternatives, adressing accuracy concerns and ensuring a consistent and reliable CT image quality analysis.

Materials and methods: Catphan600 images obtained from various CT scanners between January 2022 and June 2023 were utilized. Central images from three Catphan600 modules: CTP404 for evaluating slice thickness, geometry, and CT-number; CTP591 for modulation transfer assessment; and CTP486 for examining uniformity and noise were selected. Axial images acquired from Toshiba Aquilion Prime SP, Toshiba Astelion, GE Medical Systems Evolution EVO, and Philips Brilliance 16 were included in the study. For spiral image analysis, images acquired from Philips Iqon-Spectral CT, Philips Brilliance 16, Toshiba Aquilion Prime SP, Toshiba Astelion, GE Medical Systems Evolution EVO, and Siemens Sensation 64 were utilized. Selected images were analyzed using each software tool. The differences in mean and standard deviation between each software and IQWorks were computed and compared to tolerance levels. The differences between each software and IQWorks were tested using Wilcoxon Signed-rank paired data test.

Results: Comparing SPICE-CT with IQWorks in axial images showed no significant differences in slice thickness (P = 0.655), geometry (p = 0.294), uniformity (p = 0.721), noise (p = 0.915), average CT-number (0.12±3.41) HU (p = 1.000) with no discripancies for individual insert materials, except for Acrylic. Comparing CTQA_cp with IQWorks in axial images revealed no significant differences in slice thickness (p = 0.295), geometry (p = 0.390), uniformity (p = 0.926), noise (p = 0.275), average CT-number (0.65±3.45) HU (p = 0.880) with no significant discrepancies for individula insert materials except for Acrylic. In spiral images, no significant differences were observed between SPICE-CT and IQWorks in slice thickness (p = 0.320), geometry (p = 0.642), uniformity (p = 0.785), noise (p = 0.323), average CT-number (0.58±2.73) HU (p = 0.336) with no significant differences for individual insert materials except Delrin. Generally, MTFs exhibited significant differences ($p < 0.001$) in all cases. While SPICE-CT and CTQA_cp adhered to acceptable tolerances for most parameters, they fell short of meeting the tolerance levels for some MTFs in axial images. SPICE-CT and CTQA_cp were in agreement with IQWorks and measured most parameters within acceptable tolerance levels. However, CTQA_cp did not perform analysis for spiral images.

Conclusion: SPICE-CT and CTQA_cp were consistent with IQWorks and calculated almost all considered image quality parameters to within acceptable tolerances. However, CTQA_cp confined its analysis to axial images. Consequently, SPICE-CT emerged as a viable alternative to IQWorks for axial and spiral Catphan600 image analysis.

Dose estimation to cardiac implanted electronic device in low voltage intraoperative radiotherapy

Edith S. EL GHASSAL

selghass@ictp.it

Supervisors:
Dr. Andrea Dassie
Dr. Paola Chiovati

Centro di Riferimento Oncologico IRCCS Aviano., Italy

Objective: Intraoperative radiotherapy is a specific technique for treating breast cancer that offers several benefits. One crucial aspect of IORT is in vivo dosimetry, which measures the dose at varying distances. Can be also used to estimate the dose to cardiac implanted electronic devices and in this study we aim to estimate the safe distance for CIED. To achieve this, we need to calibrate a type of dosimeter among available dosimeters, thermoluminescence has been used to detect low dose levels. We used a low-voltage machine in our study for the delivery of radiation and a comparison of dose in patients with a water phantom to ensure an accurate estimation of this distance.

Materials & Methods: The low voltage machine is a small machine with a kV x-ray source designed specifically for IORT applications. We used this clinical machine to cross-calibrate TLD dosimeters in the clinical energy spectrum and in dose range of 0-4 Gy. During the IORT of breasts, we utilized this calibrated TLD to measure the dose at varied distances. We placed one package of TLD wrapped in a sterile envelope on the patient's skin after breast-conserving surgery to collect the dose at several distances. The data obtained from actual patients via TLD were compared thoroughly with the data collected in a water phantom using an ionization chamber and TLD.

Results: We cross-calibrated TLDs and determined that they are linear and more sensitive in the low dose range of 0.1-1.5Gy, but need a correction at doses above 1.5Gy. Using this cross-calibration, we measured skin doses during IORT treatment and estimated the dose to pacemakers. Preliminary cross-calibration showed a linear response in the relevant dose range. In vivo measurements using TLD indicated that the technique is completely safe for CIED. The dose at the location more than a certain distance where CIEDs are typically placed in patients was found to be below the threshold of 2Gy.

Conclusion: Clinical evidence was utilized to successfully complete the task. To summarize, the use of TLD in IVD to collect dose data is a viable procedure. The dose and the distance to the CIED were estimated but needed more patients for more accuracy. TLD can be employed for future measurements to well estimate the dose and distance to the CIED.

Commissioning of Elekta Versa HD WFF photon beams and clinical validation into the pinnacle treatment planning System.

Laban Festus

flaban@ictp.it

Supervisor:
Dr. Serenella Russo

Prospective/Objective: Radiation therapy is a complex process which involves many steps prior to the clinical use of the linear accelerator, each of which requires complete and through commissioning and quality assurance in order to ensure accurate delivery of the prescribed radiation dose to the target. A crucial role in the radiotherapy treatment procedure is played by the Treatment planning system (TPS) because it provides the means to plan individualized dose distributions to the target volume and organs at risk sparing. The purpose of this study is the Commissioning of the Elekta Versa HD linac newly installed in the Radiotherapy Department, the beam fitting and the dosimetric clinical validation of the Philips Pinnacle 3D dose calculation algorithm for external photon beams with flattening filter (WFF).

Materials and methods: An Elekta Versa HD linear accelerator was installed by Elekta company in the radiotherapy department. Acceptance testing was performed by the Elekta specialist together with the medical physicists of the department to verify that the machine performance meets the requested specifications. Following acceptance testing was the beam data collection for commissioning, which was performed for field size ranging from 1cm x1cm to 40 cm x 40 cm by using a single device, the microdiamond synthetic detector, because of its suitable physical characteristics. Beam data were collected with the microdiamond detector in parallel configuration in the PTW MP3 water phantom, which permits to scan the detector in three orthogonal directions in the radiation field. All the measurements were in terms of relative dose, normalized to the point of maximum dose along the beam's central axis for the depth dose curves and normalized to the central axis dose for the dose profiles. For relative field measurements a reference detector (PTW semi-flex chamber) was used in order to obtain a reference signal. Pinnacle Philips TPS was used to perform the beam fitting modelling for the dose computation and also to validate the dose output of the machine for clinical use, by employing various verification methods such as tests in homogeneous phantom and patient specific QA (PSQA). Different statistical tools such Distance To Agreement (DTA), maximum percentage difference and standard deviations, were used to evaluate the discrepancies between measured and computed doses.

Results: All the acceptance tests performed after the Linac installation are within the specified tolerances. Regarding the TPS beam modelling, measured depth dose curves and profiles are in strong agreement with TPS calculations within 2% Dose Difference (DD) in low gradient regions and 2 mm DTA criteria in high gradient regions. Beam specific calculation checks in homogenous media are in strong agreement with the IAEA recommended tolerances. PSQA checks for conformal treatments on different anatomical sites gave optimal results confirming that the dose planned in realistic situations relating to the real treatment of patients corresponds to the one actually delivered.

Conclusion: The Elekta Versa HD linac and the Pinnacle Philips TPS were successfully commissioned for external photon beams with flattening filter and are ready for clinical use.

Ospedale Santa Maria Annunziata, Florence- Italy

Feasibility study of robustly optimized intensity modulated plans with photon and proton beams in head and neck cancer.

Ganesh Subedi

ganeshundkt@yahoo.com

Supervisors:
Dr. Paola Chiovati
Dr. Stefano Lorentini

Centro di Riferimento Oncologico IRCCS Aviano, Italy.

Purpose: This study investigates the feasibility and potential of Multi Field Optimization (MFO) proton plans, Robustly Optimized Intensity Modulated Photon Therapy (RB IMXT) and Planning Target Volume (PTV) based IMXT. The study aims to compare the plan quality and evaluate the robustness.

Methodology: MFO proton plans, RB IMXT and PTV based IMXT plans were created for 3 oropharynx and 2 nasopharynx cancer patients. Plans were evaluated using dose statistics, homogeneity index, conformity number, integral dose and scoring method. Robustness of treatment plans were assessed by introducing residual uncertainties of ±3 mm along the three translational axes. In protons, an additional range uncertainty of ±3.5% was introduced. Robustness of the plans was assessed according to worst scenarios. Statistical analysis includes paired-sample student's t-test and linear regression.

Results: Averaged scores “score is the sum of assigned score for each clinical goal that is achieved” for MFO IMPT was 23%, 13% higher than PTV based IMXT and RB IMXT plan respectively ($P<0.05$). In MFO proton plan, dose to Organ At Risk (OAR) was reduced by 4% to 49% ($P<0.05$) of their dose constraints, whereas for RB IMXT and PTV based IMXT, dose constraints could not be reached in parotids, oral cavity, and submandibular glands. The mean dose variation in Clinical Target Volume (CTV)s among planning techniques for D98% was less than 1.7 % of prescribed dose. The percentage of scenarios in which the clinical goals were achieved was higher for proton plans. Strong correlation was found between the worst scenario dose with nominal ($R^2 > 0.97$) and averaged scenario dose ($R^2 > 0.99$) for CTVs in all plans.

Conclusion: CTV to PTV margins are still used in photon planning. However, for comparable robustness of the plans and CTVs coverage, robustly optimized photon plans could be alternative to PTV based plans that improves conformity and in consequence reduces dose to OARs. MFO proton plans are most effective in decreasing OARs doses and enhancing target conformity keeping the reliability of the plan in terms of its robustness and coverage. It reduce integral dose to healthy tissue that decrease toxicities to patients.

Commissioning of a stereotactic radiosurgery (SRS) oriented treatment planning system (TPS)

Mohammad Wael ALMASRI

waelalmasri1995@hotmail.com

Supervisors:
Dr. Marco Valenti
Dr. Marco Parisotto

University Hospital of Marche, Ancona, Italy

Prospective/Objective: The purpose of this thesis is to commission and validate the Monte Carlo and Pencil Beam algorithms of a Brainlab Elements Treatment Planning System (TPS) for stereotactic radiosurgery (SRS) treatments delivered with a 6 MV flattening-filter free (FFF) beam of a Varian TrueBeam STx LINAC. Comparisons with other two clinically commissioned algorithms, AAA, and Acuros XB by Varian Eclipse, are also performed.

Materials and methods: As part of our commissioning and, quality assurance process, we tested different dose calculation algorithms PB with full beam data (Full PB), both Pencil Beam and Monte Carlo with reference beam data (RBM PB/RBM MC). We compared these algorithms with Acuros XB and AAA algorithms by Varian Eclipse, performing analysis to verify accuracy for SRS photon dose calculation. Validating beam and MLC models, we conducted measurements for depth dose curves, profiles, output factors, and Jaws Leakage. Parameters like offset, gain, leaf tip width, and transmission were determined for MLC. Small field profiles were verified using Gafchromic EBT3 Films, agreeing with water phantom measurements using the microDiamond detector with gamma analysis with DTA 2%/1mm. Clinical SRS plans were calculated with various algorithms at a 1 mm dose grid size and validated with SunNuclear EasyCube Phantom measurements for treatment verification.

Results: The 6 MV FFF beam characteristics aligned well with the literature. Validation confirmed our beam and MLC models for SRS treatments. Point dose measurements for larger field sizes (1x1 cm^2) had excellent agreement (1% ± 0.5%) between the measured dose, pencil beam algorithm, and Monte Carlo algorithm. For smaller rectangular fields, Monte Carlo showed better accuracy and robustness (1% dose difference) due to its precise handling of heterogeneous materials. Acuros XB demonstrated similar accuracy to MC regarding differences from the measured dose.

Conclusion: The SRS EasyCube Phantom measurement agrees dosimetrically with the plans calculated by the Pencil Beam algorithm Full PB and both reference beam model Pencil Beam and Monte Carlo (RBM PB/RBM MC) by Brainlab, as well as the AAA, and Acuros XB dose calculation algorithm by Varian. Point dose calculation for small field dosimetry and differences using SRS EasyCube Phantom both showed that the Monte Carlo algorithm is more robust and is superior in regions of heterogeneous materials. The technical information and dosimetric data provided in this thesis will be a useful reference for other clinics/institutions that will commission the same machine energy in the BrainLab TPS.

Akouvi Odette SATSI

asatsi@ictp.it

Supervisors:
Dr. Stefania LINSALATA
Dr. Patrizio BARCA
Dr. Claudio TRAINO

Comparison between two different devices for pre-treatment QA: Arc-check and EPID

Prospective/Objective: One of the most essential tasks of the medical physics workload is to ensure patient-specific quality assurance(PSQA). However, PSQA can be a time-consuming task. International regulations(such as the European Union 2013/59/EURATOM) still recommends it, especially for complex VMAT radiotherapy treatments. To achieve optimal quality assurance on patient plans while saving time, more efficient pre-treatment PSQA methods such as EPID-based measurements are preferred. However, the AAPM TG 218 discourages it because “using EPID to obtain an integrated image for VMAT is considered PC”(Perpendicular Composite). Recently, the AAPM TG 307 reported that few studies compare traditional methods of pre-treatment PSQA(based on ionization chambers or diode arrays) with EPID measurements. Furthermore, to the best of our knowledge, none of them reports results on the Sun-Nuclear Sun-Check Patient Software. This study aims to compare PSQA obtained with the Sun-Nuclear Sun-Check Patient Software against as well-established TC(True Composite) method for pre-treatment QA, such as the Sun-Nuclear Arc-check diode array. The primary objective is to investigate the possibility of replacing traditional pre-treatment PSQA methods with EPID measurements while maintaining the same level of quality assurance.

Materials and methods: During the study, thirty VMAT plans were subjected to repeated measurement using Arc-check in a composite way and with EPID per field. For each arc, an integrated EPID image was registered. It is worth noting that all of the VMAT plans were characterized by two or three arcs. Before every measurement session, linac output was carefully measured and found to be within 0.5% of the reference value. The process of pre-treatment verification of treatment plans is crucial in ensuring the accuracy and safety of radiation therapy. In this study, pre-treatment EPID images were acquired without couch and/or phantoms, and were processed using the Per-Fraction module of the Sun-Check Patient Software. The images were converted into planar dose in water slab at the EPID level and compared with calculated dose maps obtained by the embedded Sun-Nuclear Dose-Check algorithm. Moreover, Arc-check measurements were performed in absolute dose to water after calibrating the instrument, and were compared with the TPS calculations that utilized the Varian Acuros XB algorithm in dose-to-water. The Gamma Passing Rates(GPR) for both the comparisons in absolute doses were registered with different dose-DTA criteria, including 3%2mm, 3%1mm, 2%2mm, 2%1mm, 1%2mm and 1%1mm; all global and with threshold at 10%. The study also analyzed GPR distributions for each approach, and computed the main statistic descriptors such as median, inter-quartile range, maximum and minimum. Additionally, the correlation between each GPR distribution obtained with different detectors was also computed. For the EPID measurements, the per plan GPRs, which is the average of GPR values obtained for each plan arc, were considered. Finally, the study also calculated the action limits suggested by the AAPM TG 218 for each considered dose-DTA criterium. These findings provide valuable insights into the accuracy and reliability of pre-treatment verification methods in radiation therapy, which can ultimately improve patient safety and outcomes.

Results: The report provides descriptive statistics, including the median, inter-quartile range, maximum and minimum values, of the recorded GPRs(Gamma Passing Rate) in a table format. Additionally, the action limits were calculated based on the AAPM TG 218 recommendations. For the EPID(Electronic Portal Imaging Device) measurements, the average GPR values obtained for each plan

arc were reported. The data indicates a general overlap between all the reported GPR distributions, and no further statistical analyses were conducted to compare the groups. Pearson correlation coefficients were calculated for each combination of GPRs distributions with Arc-check and EPID. The coefficients ranged from -0.23 to 0.83, representing the relationship between the 1%1mm criterion for Arc-check and 1%2mm criterion for Per-Fraction Fraction0, and between the 3%2mm criterion for Arc-check and the 3%1mm criterion for Per-Fraction Fraction0. These results provide insight into the correlation between the two measurement methods and can be used to guide further analysis and interpretation of the data.

Conclusion: Based on our evaluation of the EPID pre-treatment PSQA system Sun-Check Per-Fraction and Arc-check, utilizing a sample of thirty VMAT plans, we have determined that there are no significant differences in GPRs distributions across various dose-DTA criteria. This indicates that the EPID pre-treatment dosimetry system could potentially be utilized as a less time-consuming substitute for traditional TC pre-treatment PSQA methods like Arc-check. However, it should be noted that further data obtained from multicentric contests would be necessary to validate this conclusion. Overall, our findings provide valuable insights into the effectiveness of the Sun-Check Per-Fraction system and its potential to improve the pre-treatment PSQA process for VMAT plans.

Azienda Ospedaliero-Universitaria Pisana

AZIENDA OSPEDALIERO UNIVERSITARIA PISANA

A data driven method for quality control of head and neck treatment planning

Farah BEN HAMMOUDA

fben_ham@ictp.it

Supervisors:
Dr. Arta Sulaj
Dr. Marco Esposito

Ospedale Maggiore Trieste, Italy

Prospective/Objective: The Head and Neck (HN) radiotherapy treatment requires complex planning, and the quality may vary greatly if the plans are manually generated. In fact, plan quality mainly depends on the planner's skills and experience, as well as the time available for optimization. Additionally, when the plans are calculated, there is a lack of consideration for geometric variability between patients. The overlap volume histogram (OVH) serves as an anatomical metric that acts as a tool to link dosimetric and geometric parameters between an organ at risk (OAR) and target volume when predicting expected dose-volumes in knowledge-based planning (KBP). This work investigates the OVH and dose-volume histogram (DVH) correlation as a quality control method for HN cases, in view of automatic planning optimization.

Materials and methods: The OVH curves were generated retrospectively for 19 patients for both left and right parotids using Oncentra V4.5 planning system. The quality control process is established using two distinct methods. The first method involves the expected mathematical relation between the OVH and the DVH for each parotid, to determine if a lower dose could have been achieved. The second method utilizes statistical analysis to establish further correlation between the dosimetric data and the geometric complexity of the parotids and PTVs, incorporating multiple key DVH and OVH metrics.

Results: The expected mathematical relation between OVH and DVH reveals that 13 of our 19 cases can benefit from a possible dose reduction. Out of these 13 patients, 5 of them may need optimization only on the right parotid, 2 patients need optimization only on the left parotid and 6 of them need optimization for both left and right parotids simultaneously. The correlation analysis suggests that the patients' data can be divided into two sets. The first set where dose reduction is difficult due to PTV-parotid proximity, these are high complexity plans. The second set, where the parotids are more far from the target, are plans of lower complexity, and dose reduction could be possible.

Conclusion: The OVH method proved to be an effective quality control tool that can be used to improve volumetric modulated arc therapy (VMAT) planning optimization and reduce user inter-variability.

Robustness of lexicographic optimization based planning for cervical cancer according to different type of organ segmentation.

Nyaradzo J. Murwira.

nmurwira@ictp.it

Supervisors:
Dr. Lidia Strigari
Dr. R. Padovani

Santa Orsola Ospdale Bologna Italy

Prospective/Objective: In this study, according to literature auto-contouring is generally assessed by comparing with manual contouring, however the effect of the auto-contouring, manual contouring and auto-manual contouring is not known. The purpose of this study is to evaluate the robustness of auto-planning by creating a wish-list and using the same dosimetric constraints on the three types of contouring methods on the organ at risk.

Materials and methods: This study included a cohort of 10 cervical cancer patients treated with volumetric modulated arch therapy (VMAT) technique the prescription dose was of 50Gy in 25 fractions. Before the conduct of this research all the patient related information was anonymized deeply. A computed tomography simulation with 3mm slice thickness was used to acquire images for all the patients. The structure sets that were contoured by three different contouring type that is auto-contouring, auto-manual contouring and manual contouring. The auto-segmented contours were retrieved from the deep learning tool and were manually corrected by ROs where necessary. These contoured structure sets were then used in the auto-planning included the planning target volume PTV, bladder, bowel bag, femoral heads and rectum. The automatic planning was performed by mCycle implemented in the Monaco Elekta Solutions AB Monaco Research Version (v6.09.00), in which the lexicographic and the multi criterial-optimization are coupled with Monte Carlo calculation. Wish-list 1 was tuned according to the institutional clinical protocol to get wish-list 2 to obtain an optimal plan in a single optimization for all patient each with three different groups of contouring type. Data was exported from the TPS and imported in ProKnow. The impact of mCycle according to different contouring type were compared in terms of dose distribution and modulation complexity score. Their clinical acceptability was assessed by evaluating the plan quality index.

Results: The 120 automated planning task according to different contouring type using the wish-list 2 took 5 to 10 working days to complete clinically acceptable plans. The final dose calculation time can be estimated to 35 to 45 minutes to complete each plan. The dose comparison showed a comparable OAR spare. The PTV coverage were similar according to different contouring type auto, auto-manual and manual ($V_{95\%}$:94.567,94.539,94.748, $p>0.05$). The OAR bowel bag minus PTV no significant difference has been registered except for right femur head which registered significant differences as follows (V_{45Gy}(cc): auto 200; auto-manual 342; manual 268, $p>0.005$) and ($D_{5\%}$(Gy): auto 0.544; auto-manual 0.767; manual 1.273, $p<0.05$) respectively. The median plan quality index and MSC was (PQI: auto 36.99[2.87-52.53]; auto-manual 33.25[1.04-46.45]; manual 32.11[2.16-49.68], $p>0.05$) and (auto 0.263[0.192-0.280]; auto-manual 0.239[0.195-0.271]; 0.234[0.199-0.276], $p>0.05$) respectively, no significant difference has been registered.

Conclusion:mCycle plans according to auto, auto-manual and manual contouring of OAR were comparable to each other, with an exception of the OAR right femur head sparing which was not similar. More complex but clinically acceptable-like plans were registered similar.

ICTP- Strada Costiera, 11 I-34151 Trieste Italy
mmp@ictp.it

Via Alfonso Valerio, 2, Department of Physics,
University of Trieste, 34127 Trieste, Italy

Master in Medical Physics Alumni Association (MMPAA)

ICTP & UniTS's Medical Physics Graduates (IUMPG)